CLAIMS

1. An end effector assembly comprising:

a cutting head assembly having a body adapted to receive an orifice at an orifice location for generating a high-pressure fluid jet, and having a mixing tube positioned within the body of the cutting head assembly downstream of the orifice location;

a motion assembly coupled to the cutting head assembly via a clamp positioned around the body of the cutting head assembly; and

wherein an outer surface of the body mates with an inner surface of the clamp in a weight-bearing manner to vertically position and support the cutting head assembly.

2. The end effector assembly according to claim 1 wherein a boss is provided on the outer surface of the body, the boss resting upon a shelf provided on the inner surface of the clamp.

3. The end effector assembly according to claim 1 wherein the clamp has a quick-release mechanism allowing a portion of the clamp to be easily moved away from the body of the cutting head assembly.

4. The end effector assembly according to claim 1, further comprising a nozzle body assembly removably coupled to the cutting head assembly, the clamp holding the cutting head assembly when the nozzle body assembly is separated from the cutting head assembly, thereby allowing access to the orifice location without removing the cutting head assembly from the clamp.

5. The end effector assembly according to claim 1 wherein the clamp is provided with a triangularly arranged alignment member to position the cutting head assembly in a desired location.

6. The end effector assembly according to claim 5 wherein the triangularly arranged alignment member comprises pins that protrude inwardly from the inner surface of the clamp.

7. The end effector assembly according to claim 4 wherein the clamp further comprises an upper guide coupled to the nozzle body assembly, the upper guide vertically supporting the nozzle body assembly when the cutting head assembly is removed from the clamp.

8. The end effector assembly according to claim 1 wherein a position sensor is coupled to the clamp adjacent the cutting head assembly.

9. The end effector assembly according to claim 1, further comprising a shield coupled to an end region of the cutting head assembly, the shield surrounding an end region of the mixing tube and being made of a flexible material.

10. The end effector assembly according to claim 1 wherein the motion assembly is configured to be coupled to a bridge for motion parallel to a longitudinal axis of the bridge, the motion assembly further comprising a gimbal wrist provided with a first motor having a first axis of rotation and with a second motor having a second axis of rotation, the first and second axes of rotation being perpendicular to each other but neither parallel nor perpendicular to the longitudinal axis of the bridge when the motion assembly is coupled thereto.

11. The end effector assembly according to claim 1, further comprising a high-pressure fluid assembly coupled to the cutting head assembly, the high-pressure fluid assembly having a swivel through which high-pressure tubing passes to delivery high-pressure fluid to the cutting head assembly, the swivel allowing the high-pressure tubing to follow motion imparted by the motion assembly to the cutting head assembly.

12. The end effector assembly according to claim 1 wherein the clamp is positioned around the body of the cutting head assembly downstream of the orifice location.

13. An end effector assembly comprising:

a cutting head assembly having a body adapted to receive an orifice at an orifice location for generating a high-pressure fluid jet, and having a mixing tube positioned within the body of the cutting head assembly downstream of the orifice location;

a motion assembly coupled to the cutting head assembly via a clamp positioned around the body of the cutting head assembly; and

a nozzle body assembly removably coupled to the cutting head assembly, the clamp holding the cutting head assembly when the nozzle body assembly is separated from the cutting head assembly, thereby allowing access to the orifice location without removing the cutting head assembly from the clamp.

14. The end effector assembly according to claim 13 wherein the clamp has a quick-release mechanism allowing a portion of the clamp to be easily moved away from the body of the cutting head assembly.

15. The end effector assembly according to claim 13 wherein the clamp is provided with a triangularly arranged alignment member to position the cutting head assembly in a predefined location.

16. The end effector assembly according to claim 15 wherein the triangularly arranged alignment member comprises pins that protrude inwardly from the inner surface of the clamp.

17. The end effector assembly according to claim 15 wherein the inner surface of the clamp is configured to contact an outer surface of the cutting head assembly at three

locations around the circumference of the cutting head, such that the inner surface of the clamp forms the triangularly arranged alignment member.

18. The end effector assembly according to claim 13 wherein the clamp further comprises an upper guide coupled to the nozzle body assembly, the upper guide vertically supporting the nozzle body assembly when the cutting head assembly is removed from the clamp.

19. The end effector assembly according to claim 13 wherein a position sensor is coupled to the clamp adjacent the cutting head assembly.

20. The end effector assembly according to claim 19 wherein the position sensor is provided with a tip that is angled toward an end of the mixing tube, an end region of the tip being adjacent the end of the mixing tube.

21. The end effector assembly according to claim 13, further comprising a shield coupled to an end region of the cutting head assembly, the shield surrounding an end region of the mixing tube and being made of a flexible material.

22. The end effector assembly according to claim 21 wherein the shield is provided with a flange that matingly engages a groove provided in the end region of the cutting head assembly.

23. The end effector assembly according to claim 22 wherein the flange is telescopic thereby allowing the shield to be extended downward and upward relative to the end region of the cutting head assembly.

24. The end effector according to claim 21 wherein a disk of hard material is positioned in an upper, inner region of the shield.

25. The end effector assembly according to claim 13 wherein the motion assembly is configured to be coupled to a bridge for motion along a longitudinal axis of the bridge, the motion assembly further comprising a gimbal wrist provided with a first motor having a first axis of rotation and with a second motor having a second axis of rotation, the first and second axes of rotation being perpendicular to each other but neither parallel nor perpendicular to the longitudinal axis of the bridge when the motion assembly is coupled thereto.

26. The end effector assembly according to claim 13, further comprising a high-pressure fluid assembly coupled to the cutting head assembly, the high-pressure fluid assembly having a swivel through which high-pressure tubing passes to delivery high-pressure fluid to the cutting head assembly, the swivel allowing the high-pressure tubing to follow motion imparted by the motion assembly to the cutting head assembly.

27. The end effector according to claim 26 wherein the swivel is coupled to a valve having a diameter that is no more than 4.0 inches.

28. The end effector assembly according to claim 13 wherein the clamp is positioned around the body of the cutting head assembly downstream of the orifice location.

29. An end effector assembly comprising:

a cutting head assembly having a body adapted to receive an orifice at an orifice location for generating a high-pressure fluid jet, and having a mixing tube positioned within the body of the cutting head assembly downstream of the orifice location; and

a motion assembly coupled to the cutting head assembly via a clamp positioned around the body of the cutting head assembly, the clamp having a quick-release mechanism to allow a portion of the clamp to be easily moved away from the body of the cutting head assembly.

30. The end effector assembly according to claim 29, further comprising a nozzle body assembly removably coupled to the cutting head assembly, the clamp holding the cutting head assembly when the nozzle body assembly is separated from the cutting head assembly, thereby allowing access to the orifice location without removing the cutting head assembly from the clamp.

31. The end effector assembly according to claim 29 wherein the clamp is provided with a triangularly arranged alignment member to position the cutting head assembly in a predefined location.

32. The end effector assembly according to claim 29 wherein the clamp further comprises an upper guide coupled to the nozzle body assembly, the upper guide vertically supporting the nozzle body assembly when the cutting head assembly is removed from the clamp.

33. The end effector assembly according to claim 29 wherein a position sensor is coupled to the clamp adjacent the cutting head assembly.

34. The end effector assembly according to claim 29, further comprising a shield coupled to an end region of the cutting head assembly, the shield surrounding an end region of the mixing tube and being made of a flexible material.

35. The end effector assembly according to claim 29 wherein the motion assembly is configured to be coupled to a bridge for motion along a longitudinal axis of the bridge, the motion assembly further comprising a gimbal wrist provided with a first motor having a first axis of rotation and with a second motor having a second axis of rotation, the first and second axes of rotation being perpendicular to each other but neither parallel nor perpendicular to the longitudinal axis of the bridge when the motion assembly is coupled thereto.

36. The end effector assembly according to claim 29, further comprising a high-pressure fluid assembly coupled to the cutting head assembly, the high-pressure fluid assembly having a swivel through which high-pressure tubing passes to delivery high-pressure fluid to the cutting head assembly, the swivel allowing the high-pressure tubing to follow motion imparted by the motion assembly to the cutting head assembly.

37. An end effector assembly comprising:

a cutting head assembly having a body adapted to receive an orifice at an orifice location for generating a high-pressure fluid jet, and having a mixing tube positioned within the body of the cutting head assembly downstream of the orifice location;

a motion assembly coupled to the cutting head assembly via a clamp positioned around the body of the cutting head assembly;

a nozzle body assembly removably coupled to the cutting head assembly, the clamp holding the cutting head assembly when the nozzle body assembly is separated from the cutting head assembly, thereby allowing access to the orifice location without removing the cutting head assembly from the clamp;

a shield coupled to an end region of the cutting head assembly, the shield surrounding an end region of the mixing tube; and

a high-pressure fluid assembly coupled to the cutting head assembly, the high-pressure fluid assembly having a swivel through which high-pressure tubing passes to deliver high-pressure fluid to the cutting head assembly, the swivel allowing the high-pressure tubing to follow motion imparted by the motion assembly to the cutting head assembly.

38. The end effector assembly according to claim 37 wherein the motion assembly further is configured to be coupled to a bridge for motion along a longitudinal axis of the bridge, the motion assembly further comprising a gimbal wrist provided with a first motor having a first axis of rotation and with a second motor having a second axis of rotation, the first and second axes of rotation being perpendicular to each other but neither parallel nor perpendicular to the longitudinal axis of the bridge when the motion assembly is coupled thereto.

39. An apparatus for generating and manipulating a fluid jet comprising:

an end effector assembly coupled to a ram for motion along a vertical axis, the ram being coupled to a bridge for motion along an axis that is parallel to a longitudinal axis of the bridge, the bridge being moveable in a direction perpendicular to its longitudinal axis, the end effector assembly further comprising a cutting head assembly having a body adapted to receive an orifice at an orifice location for generating a high-pressure fluid jet, and having a mixing tube positioned within the body of the cutting head assembly downstream of the orifice location; a motion assembly coupled to the cutting head assembly via a clamp positioned around the body of the cutting head assembly; and a nozzle body assembly removably coupled to the cutting head assembly, the clamp holding the cutting head assembly when the nozzle body assembly is separated from the cutting head assembly, thereby allowing access to the orifice location without removing the cutting head assembly from the clamp.

40. The apparatus according to claim 39, further comprising a high-pressure fluid assembly coupled to the cutting head assembly, the high-pressure fluid assembly having a swivel through which high-pressure tubing passes to delivery high-pressure fluid to the cutting head assembly, the swivel allowing the high-pressure tubing to follow motion imparted by the motion assembly to the cutting head assembly.

41. The apparatus according to claim 39 wherein the motion assembly further comprises a gimbal wrist provided with a first motor having a first axis of rotation and with a second motor having a second axis of rotation, the first and second axes of rotation being

perpendicular to each other but neither parallel nor perpendicular to the longitudinal axis of the bridge.

42. The apparatus according to claim 39 wherein the cutting head assembly is coupled to a source of high-pressure fluid and to a source of abrasive.

43. An apparatus for generating and manipulating a fluid jet comprising:

an end effector assembly coupled to a two-dimensional manipulator, the end effector assembly being provided with a cutting head assembly having a body adapted to receive an orifice at an orifice location for generating a high-pressure fluid jet, and having a mixing tube positioned within the body of the cutting head assembly downstream of the orifice location;

a motion assembly coupled to the cutting head assembly via a clamp positioned around the body of the cutting head assembly; and

a nozzle body assembly removably coupled to the cutting head assembly, the clamp holding the cutting head assembly when the nozzle body assembly is separated from the cutting head assembly, thereby allowing access to the orifice location without removing the cutting head assembly from the clamp.

44. A shield for use with a high-pressure fluid jet assembly comprising:

an annular flange removably coupled to an end region of a high-pressure fluid jet assembly; and

an annular skirt extending downward from the flange, the annular skirt being formed of a flexible material.

45. The shield according to claim 44 wherein the flange is telescopic, thereby allowing the shield to be extended downward and upward along a vertical axis.

46. The shield according to claim 44 wherein a disk of hard material is positioned in an upper, inner region of the shield.

47. The shield according to claim 44 wherein the flange forms an interference fit with a groove provided in a nozzle nut coupled to a cutting head assembly of the high-pressure fluid jet assembly.

48. A motion assembly for manipulating a high-pressure fluid jet assembly comprising a gimbal wrist mounted on a ram for motion along a vertical axis, the ram being slideably mounted on a bridge for motion along a longitudinal axis of the bridge, the gimbal wrist being provided with a first motor having a first axis of rotation and with a second motor having a second axis of rotation, the first axis of rotation being at a 45° angle to the longitudinal axis of the bridge and perpendicular to the second axis of rotation.

49. The assembly according to claim 48 wherein each motor has a diameter of no more than 200 mm and length of no more than 250 mm.

50. The assembly according to claim 48 wherein each motor has a gear reduction ratio of no more than 200:1 and an encoder resolution of no more than 10,000 pulses-per-revs (PPR).

51. The assembly of claim 48 wherein each motor has a hollow shaft through which high-pressure tubing is passed to deliver high-pressure fluid to the fluid jet forming head.

52. The assembly of claim 48 wherein each of the first and second motors has a torque rating of no more than 51 Nm.

53. A motion assembly for manipulating a high-pressure fluid jet assembly comprising a first motor and a second motor forming a gimbal wrist, each motor having an actuator accuracy of no more than 3.0 arc-min and an actuator repeatability of plus or minus no more than 10 arc-sec.

54. The assembly according to claim 53 wherein each motor has a diameter of no more than 200 mm and length of no more than 250 mm.

55. The assembly according to claim 53 wherein each motor has a gear reduction ratio of no more than 200:1 and an encoder resolution of no more than 10,000 pulses-per-revs (PPR).

56. The assembly of claim 53 wherein each of the first and second motors has a torque rating of no more than 51 Nm.

57. A high-pressure fluid nozzle assembly comprising a nozzle body coupled to a valve body, an upper region of the nozzle body having a collar that is received by an inner cavity of the valve body to allow the nozzle body to be oriented in a selected position, and a threaded nut carried by the nozzle body engages threads provided on an outer surface of the valve body to couple the nozzle body to the valve while maintaining the nozzle body in the selected position.

58. A valve assembly for use in a high-pressure fluid jet system comprising a valve body containing a valve mechanism that selectively allows high-pressure fluid to flow through it when the valve body is coupled to a source of high-pressure fluid, an external surface of an end region of the valve body being threaded and engaging a nut, a collar being positioned in a recess of the end region of the valve body, an outer surface of the collar being free to move against a wall of the recess and an inner surface of the collar being threaded.

59. A clamp for coupling a high-pressure fluid jet assembly to a motion assembly, comprising:

a body having a quick release mechanism that allows a user to selectively move a first portion of the clamp away from a second portion of the clamp by hand without the use of tools, an inner region of the clamp having a triangularly arranged alignment member to position

a high-pressure fluid jet assembly in a desired location, and a guide spaced longitudinally from the first and second portions of the clamp, the guide having an aperture through which a high-pressure fluid jet assembly may extend when the clamp is coupled to a high-pressure fluid jet assembly.

60. The clamp according to claim 59 wherein the triangularly arranged alignment member comprises three pins that protrude inwardly from an inner surface of the clamp.

61. The clamp according to claim 59, further comprising a flange provided with an opening to receive and hold a sensor adjacent a mixing tube of a high-pressure fluid jet assembly when the clamp is coupled to a high-pressure fluid jet assembly.